

leading research, supporting research, and management. The first one, leading research, is probably the closest to faculty at a university, where researchers lead proposals and research projects and they set their own research agenda. The second one, supporting research, often comes in the form of proposal and research project contributions. The third one, as the name suggests, is not focused on research but on management. However, sometimes these roles may be neither sharply differentiable nor static: researchers may often lead proposals while other times supporting others' projects, and some positions may involve both research and management. Nevertheless, these three main paths represent general directions that researchers can choose as their career path goal. Of course, none of these would function properly without the support of administrative and technical staff.

Being a researcher at the DOE National Labs can be both exciting and challenging. The breadth of scientific problems studied in these environments is rich, and the opportunities for collaboration are enormous. At the same time, navigating the funding system may not be a simple task, particularly for early-career researchers. It often requires creative and out-of-the-box thinking, networking, and visibility to identify the right opportunities or to create them when they seem lacking; for example, seeking support from non-traditional agencies or funding sources.

It is important to realize that not all the DOE National Labs operate equally. They can be classified as Office of Science laboratories (such as ORNL), National Nuclear Security Administration (NNSA) laboratories (such as SNL), and others. A potentially useful tip for job seekers is that while U.S. citizenship is often required in NNSA laboratories, that is generally not the case in Office of Science laboratories.

Overall, looking back at the last eight years of my career, I see my journey at ORNL as an enriching learning experience. I got the opportunity to pursue research I am passionate about; mentor many bright students through different internship programs and postdocs; travel to many scientific meetings all over the world and grow a strong scientific network; heavily engage with the scientific community via minisymposium and workshop organization as well as participation in editorial boards, professional societies, panels, and committees; learn new topics while being involved in new collaborative research projects with multidisciplinary teams; and run my own peridynamics fracture simulations using the U.S.'s most powerful supercomputers.



Pablo Seleson

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## Modeling Jobs in the Biopharma Industry

*Helen Moore*

I held academic/research positions for the first 11 years after my PhD in differential geometry. Early during that time, I had switched from studying surfaces that minimize area to studying drug regimens that maximize efficacy and minimize toxicity. At a party, I was talking with someone about my disease modeling and regimen optimization work, and they said their company really needed someone like me. I quickly got an interview and an offer from Genentech. It was a difficult decision, but I took a leap and started a 15-year career as a math modeler in the biotechnology/pharmaceutical (biopharma) industry. I returned to academia in 2021, to join a group of mathematicians embedded in a department of medicine. I will focus here on advice to help early career mathematicians who are considering working in the biopharma industry.

I will describe skills employers are looking for in job candidates. I will then touch on topics including how to get started if your PhD is not in modeling, returning to academia from industry, alternatives to industry, and differences between careers in academia and industry. A previous article by Allen and Moore (2019) covers some different aspects and details about math modeling jobs in biopharma.

### Skills Needed for Biopharma Modeling

Mathematical, mechanistic, in-host disease models are commonly known in biopharma as quantitative systems pharmacology (QSP) models. If you are interested in a job as a QSP modeler in biopharma, here are some of the capabilities and experience that will make you a good candidate.

1. Building and working with ODE models in relevant settings
2. Familiarity with MATLAB or similar software
3. Use of appropriate sensitivity analysis methods to assess model dependencies
4. Ability to collaborate with scientists who are not modelers
5. Presentation and writing skills
6. Professionalism, including meeting timelines

When you are interviewing for a job, it is good to have examples you can discuss to demonstrate your capabilities. It's fine to use the same example to demonstrate multiple skills, but it is also good to have more than just one example overall.

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## Job Talk

You will likely be asked to give a presentation as part of your job interview. As with all presentations, it is a good idea to start by explaining why the audience should care about your presentation. What is the impact of the work? What potential is there for future impact? In addition to the conclusions, perhaps the methods used are new and/or could be applied in many other settings. Beginning with an impact statement and a brief description of what you will show, can help orient your audience and help them get as much as possible from your presentation.

There are a number of additional things you should demonstrate in your presentation. You will want to show work you have done that is relevant to the job you are applying for. But this is also a chance to showcase that you can appropriately gauge your audience. For example, if you are speaking to an audience of both modelers and non-modelers, you can explain a model by showing a representative diagram. The equations and a table of parameter values can be in the back-up slides, in case a modeler asks about those (which is very likely!). If you are speaking to an audience that is only modelers, however, the equations should be in the main presentation, although I suggest you only discuss one representative equation when you present them. The words you use in your presentation should be tailored to the audience. You might describe a model as a set of equations that captures the dynamics of the relevant mechanisms, if your audience includes non-modelers. If your audience is only modelers, you might describe the same model as a system of 14 nonlinear ODEs. In both cases you would discuss what the model represents.

Another important aspect of a presentation is how you respond when people ask questions. Are you courteous? Are you interested? Are your answers appropriate for the question? (Sometimes “I don’t know, but I will get back to you about that” is the most appropriate answer for a question.) Do you use wording that is appropriate for the questioner’s background?

## What About Different Backgrounds?

What if your mathematical work does not involve ODE modeling of biological systems? Could you still get a job in the biopharma industry? The answer is “eventually”, but you will need some additional training if your PhD work is in an area of mathematics that is not very applied. Getting a position in an academic biology lab that needs a quantitative person can give you the chance to learn more biology and relevant quantitative methods. This can give you a nice example or two to include in your industry job talk, in addition to explaining a bit about your original area of research. But how do you convince a biology professor to hire you? Doing a small independent modeling project can help, and demonstrates your interest. Here are a few ideas to get you started if you want to do this.

Taking or auditing a math biology course at your university is a good start, especially if it is project-based. Or you could use various online materials to teach yourself how to do such a project on your own. Alternatively, you could do an original project by learning some of the background of a disease, and modeling what is known in the literature. A good place to search the literature is the PubMed<sup>1</sup> database of peer-reviewed medical research, maintained by the National Institutes of Health. Unlike MathSciNet, all abstracts indexed in PubMed are freely available to everyone on the internet, which is very helpful for someone interested in a new field. In many cases, entire publications are also available for free through open access publishing. Review articles often include a diagram that summarizes understanding of the disease dynamics. These dynamics can be translated into a system of ODEs, and parameters can be taken from the literature or set to plausible values. Running simulations with different parameter values can yield initial insights into system behavior, such as what would happen if a certain pathway is turned off (e.g., if a relevant parameter is set to zero). If a disease you want to model already has a mathematical representation (which you would find by searching PubMed), then you could instead look for updated knowledge in the literature, and update the prior mathematical model.

## Returning to Academia

How easy is it to return to academia from industry? In my experience, most schools will ignore the valuable knowledge you could bring from your experience in industry, and instead evaluate you as if you had been an academic. This means you need peer-reviewed research manuscripts. In my case, I worked in some groups that did not allow me to publish anything related to my work. But thanks to the time I put in during weekends and evenings, I had a small but steady stream of publications during my 15 years in industry. I had won teaching awards while in academia, and had spent a few of my industry years teaching biopharma modeling methods and software. I also had a long track record of working and mentoring to increase diversity in multiple settings. So I was able to write the three statements required for many academic positions (research, teaching, and diversity), but had to explain gaps in my research and teaching.

Due to the academic standards applied, it can be challenging to transition to academia if you have been in industry a long time. If you want to keep such a transition as an option, you can make sure to take jobs in groups that are enthusiastic about publishing their work. And you can try to do some guest lecturing to students and have them fill out evaluation forms. Also, you can try to make a decision about returning to academia as early in your career

<sup>1</sup><https://pubmed.ncbi.nlm.nih.gov/>

as possible. A gap of a few years is not as much of an issue as 15 years is.

### Alternatives to Industry

What if you prefer an academic career, but would prefer to focus on research rather than teaching? You're in luck! There are now multiple groups of mathematicians in academic or similar settings, with a focus on research. The group I am part of at the University of Florida (UF) is called the Laboratory for Systems Medicine<sup>2</sup> directed by Reinhard Laubenbacher. We have openings for faculty and postdocs, and we are in the UF College of Medicine. Our postdocs are completely research-focused. Our faculty might have responsibilities that are 90% research and 10% teaching, and the teaching component can be satisfied by giving several lectures in a course.

In the US, there are several other groups that have a similar research focus. They also usually have postdoctoral or other job openings. These include the Computational Medicine<sup>3</sup> Program at the University of North Carolina at Chapel Hill led by Tim Elston, and the Center for Computational Oncology<sup>4</sup> at the University of Texas at Austin led by Tom Yankeelov. Within medical centers, there is the Integrated Mathematical Oncology Department<sup>5</sup> at Moffitt Cancer Center led by Sandy Anderson, and the Mathematics in Medicine Program<sup>6</sup> at Houston Methodist led by Vittorio Cristini.

### Comparison of Academia and Industry

The table to the right compares settings in which a mechanistic, in-host disease modeler might be employed.

Point of Comparison	Academic Math Department	Academic Medical Department	Biopharma Industry
Job Security	Tenure is possible	Tenure is possible, but you still need get grant funding, typically 25% or 50% of your salary	There is the potential for layoffs
Who decides what you work on?	You, when you aren't teaching	You, but you need funding agencies to agree on some projects	Your manager or someone more senior, possibly with input from you
Typical focus	Foundational/basic science	Foundational/clinical	Methods/drug development
Compensation	Academic Math	Higher than Academic Math	Higher than Academic Medical, and many companies offer performance bonuses and stock
Teaching	Typically 1 to 3 courses per semester; some schools allow buyout with grants	Usually give only a few lectures in courses; but have to spend time applying for grants	Usually work on projects full time and don't have any required teaching or grant writing
Mentoring	Can have grad students and postdocs	Can have grad students and postdocs	Sometimes
Is publishing allowed?	Yes	Yes	Many times yes, but not by all projects/groups/companies
Can you attend conferences?	Yes, with school funds you apply for, or with a grant you have	Yes, with your start-up funds or your grant money	Yes—company usually pays for at least one conference and/or training course per year; more when there is impactful work to present
Which conferences do you attend?	Society for Mathematical Biology (SMB); Society for Industrial and Applied Mathematics (SIAM)—Life Sciences (held bi-annually)	SMB; SIAM—Life Sciences; therapeutic area conferences	SMB; SIAM—Life Sciences; American Conference on Pharmacometrics (ACoP)
Can you present?	Yes—often a talk is submitted	Yes—often a poster abstract is submitted and accepted	Yes—often a poster abstract is submitted and accepted
Moving positions	Many people stay at the school where they started their career	Many people stay at the school where they started their career	Many people move jobs more than once in their career; some people work remotely, but if you don't, you can easily change jobs without moving homes if you live in a hub like Boston or San Francisco areas

<sup>2</sup><https://systemsmedicine.pulmonary.medicine.ufl.edu/>

<sup>3</sup><https://www.med.unc.edu/compmed>

<sup>4</sup><https://cco.odan.utexas.edu/>

<sup>5</sup><https://moffitt.org/research-science/divisions-and-departments/quantitative-science/integrated-mathematical-oncology/>

<sup>6</sup><https://www.houstonmethodist.org/math-in-medicine/>



## Conclusion

In this article, I have presented my own view of some aspects of a career as a mathematical modeler in the biopharma industry. If you are considering a job in industry, I recommend that you talk with others who have worked or are working in industry. You can do this by attending sessions at the Joint Mathematics Meetings such as career panels with people in industry, or by attending a meeting that industry modelers are attending (see the table above). You could also invite some of these modelers to speak in your department's applied math seminar either virtually or in-person.

## References

R. Allen and H. Moore, *Perspectives on the Role of Mathematics in Drug Discovery and Development*, *Bull Math Biol.* **81** (2019), no. 9, 3425–3435, DOI 10.1007/s11538-018-00556-y. PMID: 30693431.



Helen Moore

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# A Personal Story of a Career Trajectory to BIG

## *Marisabel Rodriguez Messan*

Deciding what to do after graduating either with a bachelor's, master's, or PhD degree in mathematics can be overwhelming; especially when your academic studies were chosen solely based on what you enjoy doing and learning the most—for me it was mathematics. In this article, I will share the story of how I got to where I am with a job as an employee of the United States (US) government and give some advice based on my experiences along the way.

I believe that where I am right now in life was largely influenced by where I came from and my upbringing. So, let's start from the beginning. I grew up in Mexico, in a

small border town to Texas. Living so close to the US and hearing about the amazing opportunities an education in the US provides made me dream of one day having such an education. Upon completing my secondary education in Mexico, I was very fortunate that my parents did everything possible to enable me and my siblings to obtain a college education in the US. Coming from a different country with a different education system and language felt overwhelming. However, it was the start of a big adventure, and my plan was to excel at all costs. I attended a predominantly Hispanic institution in the south of Texas, The University of Texas Rio Grande Valley. Although I am a Latina/Hispanic, I still felt like an outsider; this was difficult at times but in the long run I found myself striving to excel without being labeled as a minority.

At first, it was not clear which field of study I wanted to pursue. After trying a few disciplines (e.g., graphic design), I eventually decided to major in mathematics. At the time, I was not completely aware of how easy or difficult the path would be or where that would lead me after graduating. However, math felt comfortable, challenging enough, and somehow promising for a future career.

I finished my bachelor's and master's of science degrees in math at the same university. Then, I decided to pursue a PhD in applied mathematics because I felt there was more to learn not just academically but about life itself. This decision was really motivated by the fact that I attended a summer research internship out-of-state where I was exposed to many other applications of mathematics and fell in love with research. During the PhD at Arizona State University (ASU), my intellectual capabilities were challenged and stretched more than I could have ever imagined. However, I was suddenly on the path to accomplish things that previously felt unreachable. Though my time pursuing a doctoral degree in math was very challenging, it taught me to go out in the world and face almost anything.

A couple months before my PhD graduation, I started to wonder what type of job I should look for, either in academia or in business-industry-government (BIG). As graduate students we become very familiar with what the job and life of a professor looks like. We think that it is the safest path and feel afraid to look anywhere else. Although I contemplated the idea of applying for a tenure-track position, I wanted to experience something different since I felt that I've been in a school setting my entire life. However, by the time I graduated, my partner (who also graduated with his PhD a few months before me) had taken a job in a small town. When this happens, your job options narrow and you may need to make a few compromises. This was my situation, and I ended up accepting a teaching position at Dartmouth College while we determined if this is what we wanted for both of our careers. I found my experience in this teaching position very rewarding, especially mentoring minority students who approached me about my career path and were looking for guidance. It was at this moment

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